CLAIMS

1. A mixing device for use in a catalytic reactor and arranged between an upper catalyst bed and a lower catalyst bed thereof for admixing gas or vapor and liquid flowing concurrently inside the vessel of said reactor through said mutually superimposed catalyst beds, said mixing device being adapted for defining a flow path through said mixing device for said vapor and liquid flowing from said upper catalyst bed to said lower catalyst bed or vice versa, said flow path comprising:

- at least one inlet aperture of said mixing device,
- at least one outlet aperture of said mixing device,
- a first and at least one second mixing orifice or passage arranged sequentially along said flow path, said first and said at least one second mixing orifice being arranged and adapted such that substantially the entire combined flow of liquid and vapor is constrained to flow through each of said mixing orifices having such a flow-through area relative to the flow rate of said combined flow that the no-slip two-phase flow velocity of said combined flow in the mixing orifice during at least one operational phase of said reactor is between 3 m/s and 15 m/s, preferably sufficient for the liquid to be dispersed into the vapor and/or the vapor to be dispersed into the liquid, and
- an essentially horizontal flow path section extending between said at least one inlet aperture and said at least one outlet aperture such that the vertical dimension of the mixing device is as small as possible, said essentially horizontal flow path section preferably extending from proximate said inlet aperture to proximate said outlet aperture.

2. A mixing device according to claim 1, wherein said no-slip two-phase flow velocity of said combined flow in a mixing orifice is between 3.5 m/s and 14.5 m/s during at least one operational phase of said reactor.

3. A mixing device according to claim 1, wherein said first mixing orifice is provided by said inlet aperture, and a second mixing orifice is provided by said outlet aperture.

4. A mixing device according to claim 1, wherein said no-slip two-phase flow velocity in at least one mixing orifice, during at least one operational phase of said reactor, is between 4.0 m/s and 12.5 m/s.

5. A mixing device according to claim 1, and further comprising two sequentially arranged second mixing orifices, wherein said no-slip two-phase flow velocity in a mixing orifice, during at least one operational phase of said reactor is between 3.5 m/s and 10.5 m/s.

6. A mixing device according to claim 1, wherein the overall slope of said mixing device from one side thereof to the other side thereof is less than 20%, corresponding to an angle with the horizontal plane of maximum 11.5 degrees.

7. A mixing device according to claim 1, wherein said flow path downstream from a mixing orifice comprises an expanded area flow path section having such a cross-sectional area that the no-slip two-phase flow velocity in said expanded area flow path is substantially lower than the no-slip two-phase flow velocity through the corresponding mixing orifice such that increased hold time of said flow in said expanded area flow path section is provided for effecting heat and mass transfer.

8. A mixing device according to claim 7, wherein said expanded area flow path section comprises at least two flow channels for dividing said entire combined flow into at least two separate two-phase streams, said at least two channels having such a combined cross-sectional area that the no-slip two-phase flow velocity of each of the at least two separate two-phase streams is substantially lower than the no-slip two-phase flow velocity through the corresponding mixing orifice, such that increased hold time in said channels is provided for effecting heat and mass transfer.

9. A mixing device according to claim 8, wherein the at least two separate two-phase streams are of substantially the same size.

10. A mixing device according to claim 7, wherein the total cross-sectional area of said expanded area flow path section or said channels with divided flow is such that the maximum no-slip two-phase flow velocity is more than approximately 25% of the no-slip two-phase flow velocity in the upstream mixing orifice with combined flow.

11. A mixing device according to claim 7, wherein the total cross-sectional area of said expanded area flow path section is such that the minimum no-slip two-phase flow velocity is less than approximately 100% of the no slip two-phase flow velocity in the upstream mixing orifice with combined flow.

12. A mixing device according to claim 1, wherein said catalytic reactor is a vertical hydroprocessing reactor with a downward concurrent flow of vapor and liquid in which hydrocarbons are reacted with hydrogen-rich gas in the presence of a hydroprocessing catalyst.

13. A mixing device for use in a catalytic reactor and arranged between an upper catalyst bed and a lower catalyst bed thereof for admixing gas or vapor and liquid flowing concurrently inside the substantially vertical vessel of said reactor through said mutually superimposed catalyst beds, said mixing device being adapted for defining a flow path through said mixing device for said vapor and liquid flowing from said upper catalyst bed to said lower catalyst bed or vice versa, said mixing device comprising:

- a top wall provided with at least one inlet aperture,
- a bottom wall provided with at least one outlet aperture,
- a lateral wall extending between the periphery of said top wall and the periphery of said bottom wall for defining an enclosed space between said top and bottom walls,
- interior baffle walls extending between said top and bottom walls adapted for defining said flow path together with said top, bottom and lateral walls, said baffle walls furthermore being adapted for defining a first and at least one second mixing orifice or passage arranged sequentially along said flow path, said first and said at least one second mixing orifice being arranged and adapted such that substantially the entire combined flow of liquid and vapor is constrained to flow through each of

said mixing orifices having such a flow-through area relative to the flow rate of said combined flow that the no-slip two-phase flow velocity of said combined flow in the mixing orifice during at least one operational phase of said reactor is between 3 m/s and 15 m/s, preferably sufficient for the liquid to be dispersed into the vapor and/or the vapor to be dispersed into the liquid, and

said interior baffle walls together with said top, bottom and lateral walls defining an essentially horizontal flow path section extending between said at least one inlet aperture and said at least one outlet aperture such that the vertical dimension of the mixing device is as small as possible, said essentially horizontal flow path section preferably extending from proximate said inlet aperture to proximate said outlet aperture.

14. A mixing device according to claim 13, wherein the overall slope of said mixing device reckoned from at least a majority of first points on the periphery of said top or bottom wall to the respective points on said periphery of said top or bottom wall, respectively, most remote from the respective first points is less than 20%, corresponding to an angle with the horizontal plane of maximum 11.5 degrees.

15. A mixing device according to claim 13, wherein said top and bottom walls are essentially planar and preferably mutually parallel and preferably also essentially horizontal.

16. A mixing device according to 13, wherein said no-slip two-phase flow velocity of said combined flow in a mixing orifice is between 3.5 m/s and 14.5 m/s during at least one operational phase of said reactor.

17. A mixing device according to claim 13, wherein said first mixing orifice is provided by said inlet aperture, and a second mixing orifice is provided by said outlet aperture.

18. A mixing device according to 13 and comprising a single second mixing orifice, wherein said no-slip two-phase flow velocity in a mixing orifice, during at least one operational phase of said reactor, is between 4.0 m/s and 12.5 m/s.

19. A mixing device according to claim 13 and comprising two sequentially arranged second mixing orifices, wherein said no-slip two-phase flow velocity in a mixing orifice, during at least one operational phase of said reactor, is between 3.5 m/s and 10.5 m/s.

20. A mixing device according to claim 13, wherein said baffle walls are configured such that said flow path downstream of a mixing orifice comprises an expanded area flow path section having such a cross-sectional area that the no-slip two-phase flow velocity in said expanded area flow path section is substantially lower than the no-slip two-phase flow velocity through the corresponding mixing orifice such that increased hold time of said flow in said expanded area flow path section is provided for effecting heat and mass transfer.

21. A mixing device according to claim 20, wherein said expanded area flow path section comprises at least two flow channels for dividing said entire combined flow into at least two separate two-phase streams, said at least two channels having such a combined cross-sectional area that the no-slip two-phase flow velocity of each of the at least two separate two-phase streams is substantially lower than the no-slip two-phase flow velocity through the corresponding mixing orifice such that increased hold time in said channels is provided for effecting heat and mass transfer.

22. A mixing device according to claim 21, wherein said at least two separate two-phase streams are of substantially equal size.

23. A mixing device according to claim 20, wherein the total cross-sectional area of said expanded area flow path section is such that the maximum no-slip two-phase flow velocity is more than approximately 25% of the no-slip two-phase flow velocity in the upstream mixing orifice with combined flow.

24. A mixing device according to claim 20, wherein the total cross sectional area of said expanded area flow path section is such that the minimum no-slip two-phase flow velocity is less than approximately 100% of the no-slip two-phase flow velocity in the upstream mixing orifice with combined flow.

25. A mixing device according to claim 13, wherein said catalytic reactor is a vertical hydroprocessing reactor with a downward concurrent flow of vapor and liquid in which hydrocarbons are reacted with hydrogen-rich gas in the presence of a hydroprocessing catalyst.

26. A catalytic reactor having an upper catalyst bed superimposed on a lower catalyst bed and provided with a mixing device according to claim 1.

27. A catalytic reactor having an upper catalyst bed superimposed on a lower catalyst bed and provided with a mixing device according to claim 13.

28. A catalytic reactor having an upper catalyst bed superimposed on a lower catalyst bed and provided with a mixing device according to claim 13, wherein the overall slope of said mixing device reckoned from at least a majority of first points on the periphery of said top or bottom wall to the respective points on said periphery of said top or bottom wall, respectively, most remote from the respective first points is less than 20% corresponding to an angle with the horizontal plane of maximum 11.5 degrees.

29. A reactor according to claim 28, wherein said top and bottom walls are essentially planar and preferably mutually parallel and also essentially horizontal.

30. A reactor according to claim 28, wherein a lateral wall extending from the periphery of said top wall to the periphery of said bottom wall conforms in shape and size to the inner surface of the exterior wall of said reactor vessel.

31. A reactor according to claim 28, wherein said lateral wall is constituted by the exterior wall of said reactor vessel.

32. A reactor according to claim 28, further comprising means for obstructing or sealing any space between said lateral wall and the exterior wall of said reactor vessel to obtain an essentially fluid-tight joint between the mixing device and said reactor vessel wall such that the entire flow of vapor and liquid is constrained to flow through said mixing device.

33. A reactor according to claim 28, wherein the cross-sectional area of the essentially horizontal mixing device in the plane perpendicular to the reactor vessel wall is between 25% and 100% of the inner cross sectional area of said reactor vessel.

34. A reactor according to claim 26, wherein flow means are provided for causing a cold quench fluid to flow into the reactor vessel to cool down the process stream at a point upstream the first mixing orifice or between two mixing orifices.

35. A reactor according to claim 27, wherein flow means are provided for causing a cold quench fluid to flow into the reactor vessel to cool down the process stream at a point upstream the first mixing orifice or between two mixing orifices.

36. A method of admixing gas or vapor and liquid flowing concurrently inside a catalytic reactor between an upper catalyst bed and a lower catalyst bed thereof, said method comprising the steps of:

- constricting the cross sectional area of the entire combined flow of liquid and vapor a first time such that the no-slip two-phase flow velocity of said combined flow during at least one operational phase of said reactor is between 3 m/s and 15 m/s, preferably sufficient for the liquid to be dispersed into the vapor and/or the vapor to be dispersed into the liquid,
- subsequently expanding said cross sectional area a first time, and
- subsequently constricting said cross sectional area a second time such that the no-slip two-phase flow velocity of said combined flow is between 3 m/s and 15 m/s, preferably sufficient for the liquid to be dispersed into the vapor and/or the vapor to be dispersed into the liquid, and
- constraining said combined flow to follow a flow path that comprises at least one essentially horizontal flow path section extending along a substantial length of the entire flow path.

37. A method according to claim 36, wherein said substantial length is at least 50% of said entire flow path.

38. A method according to claim 36, wherein said method comprises the additional step of expanding said cross sectional area a second time after the second constriction thereof.

39. A method according to claim 36, wherein the step of expanding said cross sectional area comprises dividing said combined flow into at least two separate two-phase streams.

40. A method according to claims 36, wherein said no-slip two-phase flow velocity of said combined flow when constricted is between 3.5 m/s and 14.5 m/s during at least one operational phase of said reactor.

41. A method according to claim 36, wherein said no-slip two-phase flow velocity of said combined flow when constricted during at least one operational phase of said reactor is between 4.0 m/s and 12.5 m/s.

42. A method according to claim 38, and comprising the additional step of constricting said cross-sectional area a third time after the second expansion thereof such that the no-slip two-phase flow velocity of said combined flow is sufficient for the liquid to be dispersed into the vapor and/or the vapor to be dispersed into the liquid, wherein said no-slip two-phase flow velocity of said combined flow when constricted during at least one operational phase of said reactor is between 3.5 m/s and 10.5 m/s.

43. A method according to claim 36, wherein the method comprises the additional step of causing a cold quench fluid to flow into the reactor vessel to cool down the process stream, at a point upstream the first mixing orifice or between two mixing orifices.

44. A method according to claim 36, wherein said catalytic reactor is a vertical hydroprocessing reactor with a downward concurrent flow of vapor and liquid in which hydrocarbons are reacted with hydrogen-rich gas in the presence of a hydroprocessing catalyst.

45. A product produced by means of a method according to claim 36.